

Non-Invasive Filler Identification

Denice Forsht
Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV)
Code 5012G
2008 Stump Neck Road
Indian Head, MD 20640-5070
Phone: (301) 744-6850 x303 Fax: (301) 744-6947 E-mail: forsht@eodpoe2.navsea.navy.mil

Dr. Daniel T. Holslin
Science Applications International Corporation (SAIC)
16701 West Bernardo Drive
San Diego, CA 92127
Phone: (858) 826-9715 Fax (858) 826-9718

Document #s: N0001400WX20007; N0001400WX20012; N0001400WX20020

LONG-TERM GOALS

The Joint Service EOD community requires the capability to identify filler materials in both non-metallic and metallic cased munition items. Current technology has shown improvements in detection capabilities, but is unable to reliably discriminate clutter items from munition items. Therefore, the goal is to develop a portable system that can correctly detect and identify explosives and other filler materials in both Improvised Explosive Devices (IEDs) and Unexploded Ordnance (UXO) by non-invasive measures.

OBJECTIVES

In FY00, the NAVEODTECHDIV began exploring the use of Nuclear Quadrupole Resonance (NQR) for detecting IEDs. Since the majority of IEDs of interest were encased in non-metallic containers, the inability of NQR to penetrate and receive signals through metal was not considered a detriment. During FY00 a new requirement was introduced by the Joint Service Explosive Ordnance Disposal (EOD) community to also identify filler materials in metallic cased munitions. The objective of this task has been changed to address both the non-metallic IED and metallic munitions items requirements by a pulsed neutron technique. This technique generates high-energy neutrons that can easily penetrate thick-cased munitions. The generator can be turned on and off, eliminating the need for shielding during transportation and storage. The design will include developing a directionally sensitive detector, design changes to reduce size/weight, and fabricating a bench model and test bed. Tests will be conducted to identify the bulk detectors capabilities and limitations. As a parallel effort, a database of trace detection capabilities will begin, using the HPLC, GC/MS, and FTIR instruments. This database will be used to compare trace detector and bulk detector capabilities and limitations.

APPROACH

The PELAN (Pulsed ELemental Analysis with Neutrons) system utilizes a pulsing deuterium-tritium (d-T) neutron generator. The pulsing d-T neutron generator provides 14 MeV neutrons which in turn initiate several types of nuclear reactions ($(n,n'\gamma)$, $(n,p\gamma)$, (n,γ) etc.) on the object under scrutiny. The γ -ray from these reactions are detected by a suitable set of detectors (usually bismuth germanate (BGO) scintillators). During the neutron pulse, the γ -ray spectrum is primarily composed of γ -rays from the $(n,n'\gamma)$ and $(n,p\gamma)$ reactions on elements such as C and O, and is stored at a particular memory location within the data acquisition system. Between pulses, some of the fast neutrons that are still within the object lose energy by collisions with light elements composing the object. When the neutrons have an energy less than 1 eV, they are captured by such elements as H, N, and Fe through (n,γ) reactions. The γ -rays from this set of reactions are detected by the same set of detectors but stored at a different memory address within the data acquisition system. This procedure is repeated with a frequency of approximately 10 kHz. After a predetermined number of pulses, there is a longer pause that allows the detection of γ -rays emitted from elements such as Si and P that have been activated. Therefore, by utilizing fast neutron reactions, neutron capture reactions, and activation analysis, a large number of elements contained in an object can be identified in a continuous mode without sampling.

Research for improvements of the system will concentrate on temperature-dependent gain stabilization, signal to noise ratio, and design changes to reduce size/weight. These changes to the PELAN system will optimize the detection and identification ability of the system.

The temperature-dependent gain stabilization has had some preliminary tests conducted, where SAIC tracked the temperature changes and automatically adjusted the gain of the amplification system to compensate for the current temperature conditions of the BGO crystal. Tests will be performed with small pieces of BGO crystals to find the optimum placement of temperature probes within the pieces and also to find a method to correct the over-compensation found in preliminary tests.

The current PELAN system uses the BGO crystal as one large piece. In order for a signal to be registered by the PELAN system, the signal must travel the entire length of the crystal and enter a photomultiplier tube. The ratio of the front face area to the length of the crystal determines the amount of off-axis signal (noise) that reaches the photomultiplier tube. Cutting the crystal into smaller segments (reducing the front face area while keeping the length constant) decreases the cross-sectional area to length ratio, which in turn decreases the noise level. Also, instead of one photomultiplier tube, one preamplifier, etc. each segment has its own photomultiplier tube, preamplifier, etc. Since the height and width of an individual segment is much smaller than the original crystal size, the noise from either above or below the segment will be decreased. Also, it is very likely that a signal from above or below the segment will interact with more than one segment. Therefore, additional improvements in signal to noise ratio can be gained by using the return signal that interacts with only a single segment. This will be determined by using the data from the various segments routed into an electronic logic unit, which will identify if more than one segment received data. Therefore, if two segments receive data simultaneously, it will cancel or veto processing that data. One more advantage to increasing the number of segments is that it allows a higher overall counting rate. Since each segment has its own very fast analog-to-digital converter, the entire data set is not confined to a single path into computer memory. Therefore, the overall data rate flowing into the computer will be higher.

The size and weight of the system will be addressed to provide the optimal portability. Once optimization has been completed a bench model and test bed will be assembled. Testing will be conducted and analyzed to study the capabilities and limitations of the system.

WORK COMPLETED

Research of the applicability of Nuclear Quadrupole Resonance for the use of detecting and identifying IEDs was conducted. Initially the requirement for NQR to penetrate and receive signals through metal was not a concern, since the majority of IEDs were encased in non-metallic containers. With the new requirement introduced by the Joint Service EOD community, to identify filler material in metallic cased munition items, the research objective was modified. The need for a system to detect and identify filler material in both IEDs and UXO became apparent. Research on other nuclear interrogation systems was conducted and found to be more capable of meeting the requirement.

Through the BAA process, a contract has been awarded to Science Applications International Corporation (SAIC) and Western Kentucky University (WKU) for continued research on their Pulsed Elemental Analysis with Neutrons (PELAN) system.

RESULTS

Due to the requirements outlined, the PELAN technology was chosen. This nuclear technique shows a number of advantages for non-destructive elemental characterization. These include the ability to examine bulk quantities with speed, high elemental specificity, no memory effects from previously measured objects, a non-invasive method, and can penetrate through non-metallic and metallic materials. This project's goal is to use applied research to quantify the ability for the system to accurately and precisely fulfill the requirements needed by the EOD community.

IMPACT/APPLICATIONS

A portable bulk detection system with the capability to detect and identify explosives and filler materials in UXO and IEDs will enable the Joint Service EOD community to distinguish the clutter from the hazards in the field. Once the hazards are known, the proper tools and procedures can be identified and used to dispose of the hazard safely, reducing costs, time, and potential risk to personnel.

TRANSITIONS

Ongoing results from this project will feed directly into the Non-Intrusive Filler Detector Analysis of Alternatives (AOA).

RELATED PROJECTS

An AOA has begun to investigate the use of state of the art nondestructive test inspection equipment to determine if they provide a portable, easy to use method of distinguishing between fillers.

ESTCP is funding Western Kentucky University to demonstrate the use of the current PELAN system for UXO environmental remediation use.

TWSG is funding Western Kentucky University for the current PELAN system for use on counter-terrorism and contraband terrorism.

REFERENCES

Holslin, Dr. Daniel T., 2000. Man-Portable Inspection System for Characterization of Unexploded Ordnance, SAIC Proposal for SOL DAA B15-00-R-1001, April.

McCubbin, Ned, Notional Concept for Non-Invasive Filler Identification.